Abstract

Analysis of vibration of systems with uncertainty in material properties under the influence of a random forcing function is an active area of research. Especially the characterization based on mode shapes and frequencies of linear vibrating systems leads to much discussed random eigenvalue problem, which repeatedly appears while analyzing a number of engineering systems. Such analyses with conventional schemes for significant variation of system parameters for large systems are often not viable because of the high computational costs involved. Appropriate tools to reduce the size of stochastic vibrating systems and efficient response calculation are yet to mature. Among the mathematical tools used in this case, polynomial chaos formulation of uncertainties shows promise. But this comes with the implementation issue of solving large systems of nonlinear equations arising from Bubnov-Galerking projection in the formulation. This dissertation reports the study of such dynamic systems with uncertainties characterized by the probability distribution of eigensolutions under a stochastic finite element framework.

In the context of structural vibration, the determination of appropriate modes to be considered in a stochastic framework is not straightforward. In this dissertation, at first the choice of dominant modes in stochastic framework is studied for vibration problems. A relative measure, based on the average energy contribution of each mode to the system, is developed. Further the interdependence of modes and the effect of the shape of the load on the choice of dominant modes are studied. Using these considerations, a hybrid algorithm is developed based on polynomial chaos framework for the response analysis of a structure with random mass and stiffness and under the influence of random force. This is done by using modal truncation for response analysis with in a Monte Carlo loop. The algorithm is observed to be more efficient and achieves a high degree of accuracy compared to conventional techniques.

Considering the fact that the Monte Carlo loops within the above mentioned hybrid algorithm is easily parallelizable, the efficient implementation of it depends on the SFE solution. The set of nonlinear equations arising from polynomial chaos formulation is solved using matrix-free Newton's iteration using GMRES as linear solver. Solution of a large system using a iterative method like GMRES necessitates the use of a good preconditioner. Keeping focus on the parallelizability of the algorithm, a number of efficient but cheap-to-construct preconditioners are developed and the most effective among them is chosen. The solution process is parallelized for large systems. The scalability of solution process in conjunction with the preconditioner is studied in details.